

NASA TECHNICAL MEMORANDUM

NASA TM-7757

W. KASPRZYK AIRFOIL. THE FIRST WIND-TUNNEL TESTS

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NASA-TM-7757 19840025309

Translation of "Skrzydło W. Kasprzyka--wstępne badania
tunelowe," Technika Lotnicza i Astronautyczna, Vol. 30,
No. 9, September 1975, pp. 9-10

LANGUAGES
ENGLISH
FRENCH
GERMAN
ITALIAN
JAPANESE
KOREAN
RUSSIAN
SPANISH
SWEDISH
THAI
VIETNAMESE
CHINESE
HINDI
ARABIC
HEBREW
YIDDISH
OTHER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546
OCTOBER 1984

STANDARD TITLE PAGE

1. Report No. NASA TM-77757		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle W. KASPRZYK AIRFOIL. THE FIRST WIND-TUNNEL TESTS				5. Report Date October 1984	
				6. Performing Organization Code	
7. Author(s) Tadeusz Wusatowski				8. Performing Organization Report No.	
				10. Work Unit No.	
9. Performing Organization Name and Address Leo Kanner Associates Redwood City CA 94063				11. Contract or Grant No. NASW-3541	
				13. Type of Report and Period Covered Translation	
12. Sponsoring Agency Name and Address National Aeronautics and Space Adminis- tration, Washington, D.C. 20546				14. Sponsoring Agency Code	
15. Supplementary Notes Translation of "Skrzydło W. Kasprzyka--wstępne badania tunelowe," Technika Lotnicza i Astronautyczna, Vol. 30, No. 9, September 1975, pp. 9-10. (A76-11893)					
16. Abstract The Kasprzyk slotted-flap glider airfoil (the Kasper wing) enabling glider flight at 32 km/h and 0.5 m/sec descent speed was wind-tunnel-tested in the U.S. The test layout is described and reasons offered for discrepancies between wind-tunnel results and Polish in-flight data: high induced drag caused by relative size of model wing span and tunnel, by vortex attenuators on the model and their proximity to the tunnel wall, nonsimilarity between flow over a smooth wing and flow over the Kasprzyk wing with bound vortices, obstruction of the tunnel test chamber cross section by the model wing, discrep- ant Reynolds numbers, and model airfoil aspect ratio much smaller than the prototype. The overall results offer partial confirmation of the Kasprzyk theory, but further in-tunnel and in-flight studies are recommended.					
17. Key Words (Selected by Author(s))			18. Distribution Statement Unclassified - Unlimited		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified		21. No. of Pages 8	22.	

N84 33380#
A76-11893#
N-154, 937

W. KASPRZYK AIRFOIL. THE FIRST WIND-TUNNEL TESTS

Tadeusz Wusatowski

Recently Technika Lotnicza i Astronautyczna (No. 9, 1974) /9* published an article about a slotted-flap glider airfoil and a glider designed by Witold Kasprzyk. Daniel Walton, a senior student at the University of California, also found out about the unique aerodynamic characteristics of the Kasper wing, making possible glider flight at 32 km/h and 0.5 m/s descent speed. Because these data were controversial and not officially confirmed, he decided to study this problem as part of his semester work at the University. He conducted the tests in the Northridge low-speed wind tunnel, and was well aware of the fact that model wind-tunnel tests could not be more accurate than accurate measurements made during flight. Below we publish the report on his tests and their results (taken from the journal Soaring, No. 11, 1974).

The purpose of the study was to obtain specific quantitative data about an interesting method for increasing aerodynamic lift at large angles of attack, which was possible thanks to the collaboration of a system of flaps, sustaining vortices above the upper airfoil surface. A rectangular wing with a 48.3 cm span and 15.2 cm chord was produced for the wind-tunnel tests. Two edge plates were placed at its ends, which were also used for mounting the flaps at the leading edge and the slotted flaps at the trailing edge. The latter were obtained by bending steel sheet (approximate thickness 1.6 mm) according to the shape shown in Fig. 1. The entire wing of the model was carefully polished. The tests were carried out in a wind tunnel whose test chamber was 71 cm wide and 50.8 cm high, with three points for clasping the model.

*Numbers in the margin indicate pagination in the foreign text.

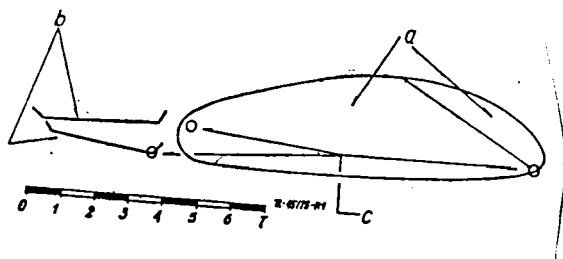


Fig. 1. Wing model airfoil:
a) pine wood elements of airfoil;
b) flaps from 1.6 mm metal sheet;
c) pivoting points.

Dynamometers and an electronic counter were used to measure the lift and drag. It turned out that a sufficiently high speed of flow around the airfoil for the Reynolds number equality for the model and the real airfoil could not be used in the wind tunnel because of the dynamometer loads which were calibrated in the range to 4.5 kg. In order not to overload and damage the expensive measurement system, the measurements were made at lower speeds, which were 31.4 m/s and 22.2 m/s, respectively.

A somewhat undesirable feature of the model of the wing was the small vibrations of the slotted flap at the trailing edge which occurred at small angles of attack. However from a practical standpoint these vibrations are of no importance, because under normal flight conditions the flaps are closed.

Visualization of flow was carried out during the wind-tunnel tests. The method of filaments glued to the airfoil surface was used because of the lack of a smoke generator in the wind tunnel. After the model was positioned at large angles of attack at which the occurrence of the vortex phenomenon was anticipated, the tunnel was put in operation and the velocity of the flow was gradually increased. In the range of low velocities the flow around the airfoil behaved in a normal manner, and at higher velocities, the direction of the flow changed to the opposite direction. Initially the point at which the direction changed was unstable, however, with increasing velocity, the reverse flow stabilized (Fig. 2). This reversed flow indicated the existence of a vortex behind the leading edge (as described in

TLiA, No. 9, 1974, p. 18). Visual observation confirmed the existence of a similar vortex behind the trailing edge.

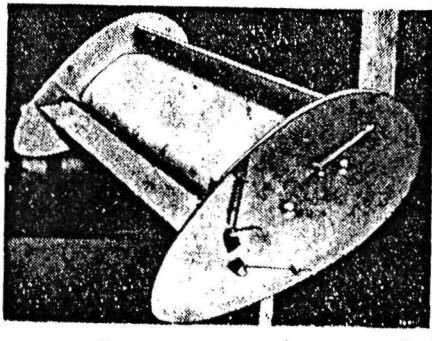


Fig. 2. Model in wind tunnel, visible filaments indicate reverse flow around the body on upper surface of wing with open flaps.

Subsequent observations were made at a number of other large angles of attack, always with the same positive result. Only the velocity at which the flow changed direction decreased commensurately with increasing angle of attack. Next the lift and drag were measured at a con-

stant velocity in the entire range of angles of attack (Fig. 3). The model with open flaps was tested at two different speeds, the only difference being that at the lower speed it was possible to investigate the entire range of angles of attack up to 55° (on account of dynamometer loads).

The results presented in the diagrams (for open flaps) show considerable differences in the drag and lift compared with more conventional airfoils (Figs. 4 and 5). An airfoil with retracted flaps gives graphs which are similar to those of a conventional airfoil presented in Fig. 3.

From Fig. 4 it is evident that at greater speed and with open flaps the wing does not tend to stall in the usual sense of the word. In general the drag of the wing turned out to be very great and did not increase parabolically with increasing angle of attack as in other airfoils. The mentioned region which lies in the range of angles of attack from 19° to 30° is clearly marked in Figs. 4 and 5. Figure 6 gives the gliding ratio of the wing, i.e. C_z/C_x for closed flaps at a 31.4 m/s speed and for open flaps at a speed of 22.2 m/s. This gives rise

to a difference in Reynolds numbers, however, for smaller speeds the variation in C_z/C_x could be investigated in a greater range of angles of attack. The optimal angle of attack for a smooth airfoil lies at smaller angles of attack, whereas for an airfoil with open flaps, at greater angles of attack. This indicates that a Kasprzyk airfoil meets best the requirements at greater angles of attack. Two numbers pertaining to the descent speed at great angles of attack were given beforehand, namely 1.02 m/s at 48.2 km/h and 0.51 m/s at 32.2 km/h. From the equality $C_z/C_x = v/w$, which is important for small angles of attack, it follows that the gliding ratio in the given cases is 13.3 and 17.6, respectively. These quantities contradict the maximum value of the gliding ratio obtained in experiments, which is equal to 1.6.

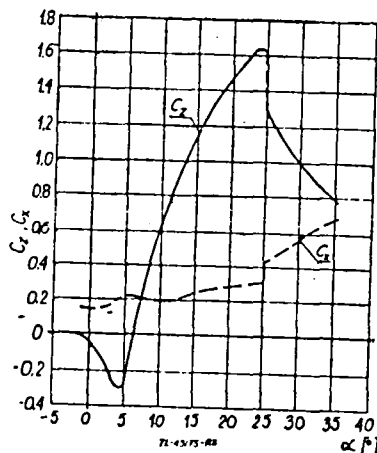


Fig. 3. Graph of C_z and C_x as function of angle of attack for system with retracted flaps, velocity $v = 31.4$ m/s, $Re = 330,000$.

During the tests $C_{z \max} = 2.98$ was obtained at a 50° angle of attack, however the drag was always considerable. During visualization of the flow it was ascertained that the flaps give rise to a vortex system. Flutter of the buffeting type also occurred. It was assumed that the tests would not be extensive and that their purpose was to test a prototype airfoil in a wind tunnel and obtain more

detailed information about the advantages and limitations resulting from the use of an unusual system of flaps. This is how D. Walton summarized his study.

Now we will try to give some thought to what the description of the tests which was presented above means.

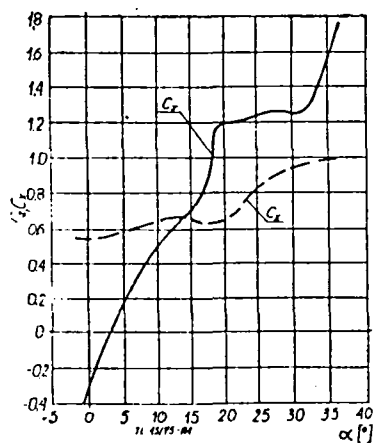


Fig. 4. Graph of C_z and C_x as a function of angle of attack, open flaps, flow velocity $v = 31.4$ m/s, $Re = 330,000$.

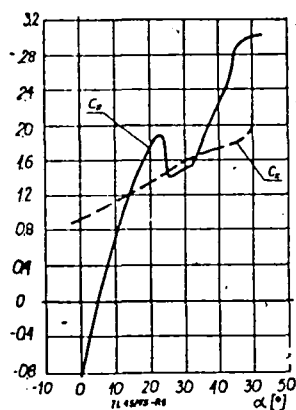


Fig. 5. Graph of C_z and C_x as a function of angle of attack, open flaps, flow velocity $v = 22.2$ m/s, $Re = 226,000$.

* The obtained $C_{z \max} = 2.98$ comes close to the value obtained by W. Kasprzyk during flight, i.e. 3.15.

* The excessive drag, which resulted in a small gliding ratio, was due to the measurement method used, namely:

-- plane flow around the airfoil was not obtained in the wind tunnel because the wingspan did not take up the entire width of the wind tunnel;

-- the edge plates that were used, which stabilized the vortex and are used to obtain a plane flow are too small for this purpose and may cause great induced drag, especially

since the maximum angles of attack at that time are about 55° and the aspect ratio of the model wing is 3.17. These values give an induced drag coefficient C_x approximately equal to 1 (we recall that the aspect ratio of the Kasprzyk wing is 15);

-- mounting the edge plates of the wing at a distance of about 10 cm from the wind tunnel walls must have caused

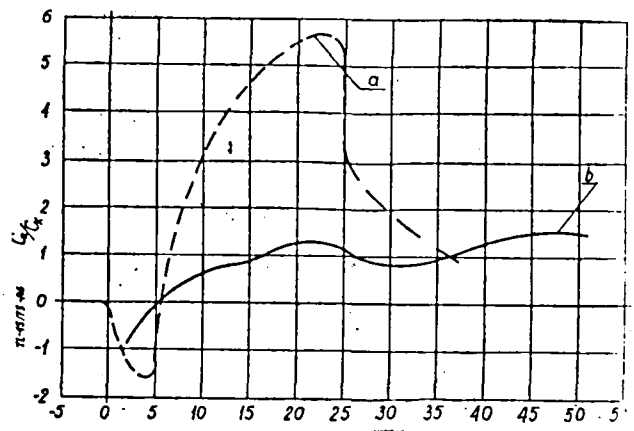


Fig. 6. Gliding ratio of model as function of angle of attack: a) retracted flaps; b) open flaps.

increased turbulence and consequently also increased drag (this method is normally not used);

-- the flow around a straight wing (model) and a backswept wing (Kasper wing) cannot be compared since a bound vortex occurs on them, at which time these

vortices differ somewhat, and the drag of the straight wing is greater;

-- the condition of equality of Reynolds numbers which was not satisfied (the number was too small for the model) increases the drag coefficient C_x for the model;

-- at very large angles of attack (the most important angles), throttling could have occurred in the wind tunnel because the wing of the model set in this position constituted a considerable part of the cross-sectional area of the chamber in which the measurements were made.

The obtained results confirm only partially W. Kasprzyk's theory, however in no case provide further substantiation of it. The problem that was described is still not fully understood and requires further, more reliable testing in a wind tunnel and during flight.

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